

# (12) UK Patent Application (19) GB (11) 2 280 372 (13) A

(43) Date of A Publication 01.02.1995

(21) Application No 9319273.0

(22) Date of Filing 17.09.1993

(30) Priority Data

(31) 9315614

(32) 28.07.1993

(33) GB

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(51) INT CL<sup>6</sup>

A61L 27/00 17/00

(52) UK CL (Edition N )

A5R RAG REL R111 R116

C3H HH1 H201 H202 H220 H230

D1R RFA R162 R307 R317 R502 R508 R631 R648

U1S S1035 S1036 S1328 S2410 S2416

(56) Documents Cited

None

(58) Field of Search

UK CL (Edition L ) A5R RAG RAM RAP REL , D1R RFA  
RFZ

INT CL<sup>5</sup> A61L 17/00 27/00

ONLINE DATABASES: WPI, MEDENG.

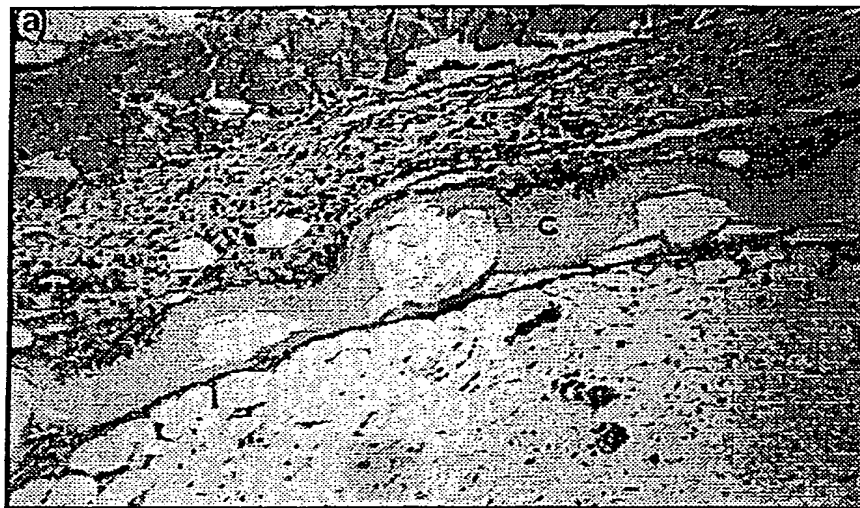
## (54) Composite surgical material

(57) A composite surgical material comprises a collagen matrix reinforced by a layer of a synthetic bioabsorbable material such as polylactide/polyglycolide or oxidised regenerated cellulose, and wherein oil droplets are dispersed in the collagen matrix. The composite, in the form of a sheet or a tube, is especially useful as a temporary, fully bioabsorbable prosthesis, for membranes or blood vessels where a highly leak-proof prosthesis is required. A method of making a composite surgical material comprises the steps of: providing a layer of a synthetic bioabsorbable material; providing a dispersion of collagen in an oil-in-water emulsion; coating at least one face of the layer of bioabsorbable material with the said dispersion; and drying the composite material thus obtained.

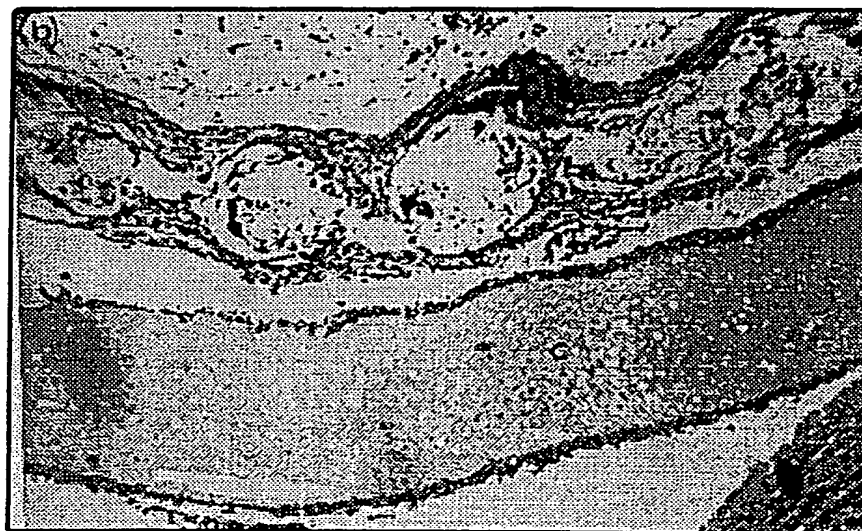
The collagen matrix may also contain a pharmacologically active agent.

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**FIG.1**



**FIG.2**



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COMPOSITE SURGICAL MATERIAL

The present invention relates to bioabsorbable composite surgical materials, processes for their preparation and also  
5 the use of such materials for the preparation of surgical prostheses and the like.

The use of bioabsorbable materials (also called resorbable materials or absorbable materials) in surgery is  
10 by now quite well known. The materials undergo gradual degradation when they are introduced into the human or animal body. This degradation results from hydrolysis which takes place on contact with living tissue in the presence of proteolytic enzymes contained therein. The hydrolysis  
15 fragments from the hydrolysis of the bioabsorbable materials are non-toxic and readily absorbed by the human or animal body.

For example, bioabsorbable surgical sutures made from  
20 copolymers of lactic and glycolic acids are in widespread use. Such sutures do not need to be removed from the wound site after wound healing is complete. Instead, the sutures undergo slow hydrolysis and absorption by the body.

25 Other bioabsorbable surgical materials have been used as temporary prostheses in repair surgery. For example, sheets of bioabsorbable material may be used as prostheses for regions of the pericardium or the peritoneal membrane. Healing of the damaged membrane takes place from the edges  
30 of the prosthesis, and the prosthesis is gradually absorbed as healing progresses.

Likewise, tubes of bioabsorbable surgical material have been used as arterial grafts. Once again, healing of the  
35 damaged artery is accompanied by gradual resorption of the graft.

EP-A-0194192 describes a bioabsorbable composite

material that is especially suitable for use as a surgical prosthesis. The material comprises a sheet of reconstituted collagen reinforced with a mesh of a synthetic bioabsorbable polymer such as polylactic/polyglycolic acid or oxidised regenerated cellulose. The composite material is sufficiently strong to be used as an arterial graft or the like, and in particular is strong enough to hold sutures. The reconstituted collagen sheet fills all of the interstices in the mesh and renders the composite material leak-proof. The leak-proofing effect is especially important when the material is to be used to repair blood vessels. Furthermore, it has been found that the reinforced collagen films are absorbed more slowly in vivo than non-reinforced collagen films.

15 A defect of the reinforced collagen films described in EP-A-0194192 is that the film does not remain leak-proof in use for a sufficiently long time to be usable for some surgical applications. This is to say, the rate of bioabsorption of the collagen is sufficiently rapid that in some cases the film may start to leak through the interstices of the reinforcing mesh before wound healing is complete.

25 The rate of absorption of collagen in vivo can be reduced by chemical cross-linking of the collagen with succinimide or glutaraldehyde. However, such chemical treatment necessarily renders the collagen less biocompatible.

30 It has now been found that reinforced collagen films similar to those described in EP-A-0194192 may be made with significantly improved leak-proofing characteristics by incorporating oil droplets into the collagen layer.

35 The present invention provides a composite surgical material comprising a collagen matrix reinforced by a layer of a synthetic bioabsorbable material and having oil

droplets dispersed in the collagen matrix.

Preferably, the oil droplets comprise from 2% to 75% by weight of the composite material, more preferably from 5% to 50% by weight of the composite material, and most preferably  
5 from 10% to 40% by weight of the composite material.

The oil droplets are preferably microdroplets such that at least 90% of the droplets have diameters in the range  $0.1\mu\text{m}$  to  $250\mu\text{m}$ . More preferably, at least 90% of the  
10 droplets have diameters in the range  $1\mu\text{m}$  to  $50\mu\text{m}$ .

The oil droplets are preferably distributed uniformly throughout the collagen matrix. However, in certain embodiments, the oil droplets may be distributed non-  
15 uniformly, for example to provide different rates of bioabsorption of the collagen matrix in different regions of the composite material.

The oil may be any bioabsorbable and biocompatible oil.  
20 For example, vegetable oils such as corn oil, sunflower seed oil, sesame seed oil or linseed oil may be used. The term "oil" also encompasses oleaginous materials, such as lanolin, that are solid or semisolid at room temperature.

25 The collagen matrix preferably comprises insoluble fibrous collagen, such as insoluble Type I and/or Type III collagen fibres. The collagen matrix may additionally comprise soluble collagen, such as gelatin or atelocollagen, or acid - soluble collagen, or even collagen fibres  
30 reconstituted from these soluble collagens. The collagen may be obtained from any animal, fish or avian source, but is preferably obtained from bovine corium.

The relative amounts of the collagen matrix and the  
35 synthetic bioabsorbable material in the composite surgical materials according to the present invention may vary widely, depending on the intended use of the materials and the desired rate of bioabsorption. The composite materials

preferably contain from 10% to 95% by weight of the collagen matrix (including the oil droplets and any other substances dispersed therein). Preferably, the composite materials contain from 20% to 60% by weight of the collagen matrix.

5

The reinforcing layer is formed from a synthetic bioabsorbable material. Preferred synthetic bioabsorbable materials include synthetic suture materials such as polymers or copolymers of lactic and/or glycolic acids. 10 Other preferred synthetic bioabsorbable materials include modified celluloses, such as oxidised regenerated cellulose. Particularly preferred synthetic bioabsorbable materials include the polylactic/polyglycolic acid copolymer sold under the Registered Trade Mark VICRYL and the oxidised 15 regenerated cellulose sold under the Registered Trade Mark SURGICEL.

The layer of synthetic bioabsorbable material is preferably in the form of a knitted, woven or non-woven mesh 20 or web. This arrangement combines flexibility with sufficient strength for the composite material to hold sutures. The foraminous nature of these reinforcing layers also assists suturing. The mesh size selected for the layer of synthetic bioabsorbable material can vary widely, 25 depending on the particular surgical application that is envisaged.

The composite surgical materials according to the present invention preferably further comprise 30 pharmacologically active agents dispersed in the collagen matrix. Preferred pharmacologically active agents include antibiotics, antiseptics, anti-inflammatory agents and agents that promote wound healing, such as cytokines or glycosaminoglycans (e.g. hyaluronic acid and its salts, 35 heparin and the like). The pharmacologically active agents are preferably present in an amount of 0.01%-5% by weight, more preferably 0.01%-1% by weight based on the total weight of the composite material. It will be appreciated that the

presence of the oil droplets allows oleophilic active agents to be dispersed in the collagen matrix as well as hydrophilic active agents.

The composite surgical materials according to the present invention are preferably in the form of a flat sheet or a tube.

The present invention also encompasses the use of the above composite surgical materials for the preparation of a bioabsorbable surgical graft or prosthesis. For example, flat sheets of the material according to the present invention may be used as membrane grafts for repair of the peritoneum or pericardium. Tubes of the material according to the present invention may be used as grafts for the repair of blood vessels. It has been found, surprisingly, that the sheets and tubes of material according to the present invention remain leak-proof for substantially longer than corresponding materials prepared in accordance with EP-A-0194192.

20

The present invention also provides a process to prepare a composite surgical material comprising the steps of: providing a layer of a synthetic bioabsorbable material; providing a dispersion of collagen in an oil-in-water emulsion; coating at least one face of the layer of synthetic bioabsorbable material with the said dispersion; and drying the composite material thus obtained.

Preferably, the step of providing a dispersion of collagen in an oil-in-water emulsion comprises adding the collagen and the oil to water followed by emulsifying the oil at high shear. Emulsifiers may be added to assist this process, but are not always necessary, since collagen is an effective emulsifier. Where the oil is a solid or semisolid oleaginous material at room temperature (e.g. lanolin), the emulsification step is carried out at an elevated temperature, at which the oil is liquid.

Preferably, the weight ratio of collagen to oil in the emulsion is from 10:1 to 1:10, more preferably is from 2:1 to 1:5, and most preferably it is from 1:1 to 1:3. Preferably, the concentration of collagen in the emulsion is  
5 from 0.05% w/v to 10% w/v, more preferably 0.1% w/v to 5% w/v.

Preferably, the collagen, oil and synthetic bioabsorbable polymer are as defined above for the preferred embodiments of the composite surgical material according to  
10 the present invention.

Specific embodiments of the present invention will now be described further, by way of example, with reference to the accompanying Figures, in which:

15

Figure 1 shows a photomicrograph of a cross section through a collagen/vicryl film subcutaneous implant after 14 days; and

20

Figure 2 shows a photomicrograph of a cross section through a collagen/oil/vicryl film subcutaneous implant (500% oil/collagen w/w) after 14 days.

#### Example 1

25

Reinforced collagen films according to the present invention are prepared as follows.

Fibrous collagen obtained from bovine corium, prewashed  
30 to remove the majority of non-collagenous components as described in US-A-4614794 or US-A-4320201 is suspended in clear, deionised pyrogen-free water and homogenised to a fine fibrous suspension by passage through a homogenising system, such as that described in US-A-4320201. The  
35 collagen suspension is then acidified by addition of acetic acid at a concentration of 0.05M. The concentration of collagen fibres in the dispersion is 0.5% w/v.



To this suspension is added sesame seed oil at 50%, 100%, 200%, or 500% (as % of the collagen content, w/w). The mixture is homogenised to form an emulsion, degassed under vacuum, and poured into trays. In the trays a mesh of  
5 poly(L-lactide) poly(L-glycolide) (supplied by Ethicon Inc. under the Registered Trade Mark VICRYL, style 9) is immersed in the collagen/oil emulsion. The emulsions are dried in air at room temperature to form films.

10 For comparison purposes a film was made in identical fashion, but with zero oil content.

#### Example 2

15 The permeability to physiological saline of films prepared in accordance with Example 1 is determined as follows.

Pieces of collagen/oil/Vicryl™ film (oil content with  
20 respect to collagen: 0 (comparative example), 50%, 200%, 500%) are clamped between two hollow, flanged, cylindrical chambers (2.5cm diameter) to form a water-tight seal. This apparatus is suspended vertically over a beaker in a humidified chamber at 37°C. 25 ml of phosphate-buffered  
25 saline is placed in the upper chamber. The volume permeating through the film is collected in the beaker and measured daily, at which time the volume of saline in the upper chamber is replenished to 25ml.

30 The results are expressed as the cumulated volume of saline which has passed through the films. During the first 9 days there is no significant difference in permeability between the different films. However, from days 10 to 17 there is a significant variation in permeability which  
35 correlates with the oil content of the films:

	Oil content (%)	vol.(ml)days 1-9	vol.(ml)days 10-17
	0 (comparative)	81	137
	50	70	106
	200	74	101
5	500	82	82

### Example 3

The effect of oil content on the susceptibility of reinforced collagen films to degradation by collagenase is determined as follows.

Pieces of film prepared as in Example 1 are cut to give a collagen content of approx. 50mg. These are incubated at 37°C in 32.5 ml of Tris buffer (pH7.2) containing bacterial collagenase (Clostridiopeptidase A) at 50 U/ml for 2.5h. collagen degradation is measured by hydroxyproline assay of aliquots of the supernatant solution after centrifugation, and expressed as a % of the starting collagen content of the sample.

20

Collagen degradation was significantly decreased in films containing oil at 200% and 500% of the weight of collagen (degradation: 63.9% and 49.2%, respectively, compared with 85.0% degradation of collagen film containing no oil).

25

### Example 4

The effect of oil content on the susceptibility of reinforced collagen films to degradation *in vivo* is determined as follows.

30

Pieces of film (0.5cm x 1cm) prepared as in Example 1 are implanted subcutaneously in 10wk old Wistar rats, which are sacrificed at 7 and 14 days. The implant and surrounding tissue are excised, fixed, paraffin-wax embedded, sectioned and stained with haematoxylin/eosin. All the films containing oil have retained their integrity and showed significantly less degradation than those without

35

oil at both time-points. This is illustrated in the Figures, in which the remaining reinforced collagen film after 14 days is labelled C. The oil-free film in Figure 1 (comparative example) clearly shows more degradation than  
5 the film according to the present invention shown in Figure 2.

The above embodiments have been described by way of example only. Many other embodiments falling within the scope of the accompanying claims will be apparent to the  
10 skilled reader.

CLAIMS

1. A composite surgical material comprising a collagen matrix reinforced by a layer of a synthetic bioabsorbable material and having oil droplets dispersed in the collagen matrix.  
5
2. A composite surgical material according to claim 1, wherein the oil droplets comprise from 1% to 75% by weight  
10 of the composite surgical material.
3. A composite surgical material according to claim 1 or 2, wherein the oil droplets comprise from 5% to 50% by weight of the composite surgical material.  
15
4. A composite surgical material according to any preceding claim, wherein the oil droplets comprise from 10% to 40% by weight of the composite surgical material.
- 20 5. A composite surgical material according to any preceding claim wherein the synthetic bioabsorbable material comprises a polymer or copolymer of lactic acid and/or glycolic acid.
- 25 6. A composite surgical material according to any preceding claim wherein the synthetic bioabsorbable material comprises oxidised regenerated cellulose.
7. A composite surgical material according to any preceding claim wherein the layer of synthetic bioabsorbable material  
30 is a knitted, woven or non-woven mesh or web.
8. A composite surgical material according to any preceding claim, further comprising an antibiotic, an antiseptic or an anti-inflammatory.  
35
9. A composite surgical material according to any preceding claim further comprising a growth factor, a cytokine or a glycosaminoglycan.

10. A composite surgical material according to any preceding claim which is in the form of a sheet or a tube.
- 5 11. Use of a composite surgical material according to any preceding claim for the preparation of a surgical graft or prosthesis.
12. A process to prepare a composite surgical material  
10 comprising the steps of:  
    providing a layer of a synthetic bioabsorbable material;  
    providing a dispersion of collagen in an oil-in-water emulsion;  
    coating at least one face of the layer of synthetic  
15 bioabsorbable material with the said dispersion; and  
    drying the composite material thus obtained.
13. A process according to claim 12 wherein the step of  
providing a dispersion of collagen in an oil-in-water  
20 emulsion comprises mixing the collagen and the oil with water followed by emulsifying the oil.
14. A process according to claim 12 or 13, wherein the collagen comprises insoluble fibrous collagen.  
25
15. A process according to claim 12, 13 or 14, wherein the weight ratio of collagen to oil in the said emulsion is from 10:1 to 1:10.
- 30 16. A process according to claim 15, wherein the weight ratio of collagen to oil in the said emulsion is from 2:1 to 1:5.
17. A process according to claim 16, wherein the weight  
35 ratio of collagen to oil in the said emulsion is from 1:1 to 1:3.
18. A process according to any of claims 12 to 17, wherein

the synthetic bioabsorbable material comprises a polymer or copolymer of lactic acid and/or glycolic acid.

19. A process according to any of claims 12 to 18, wherein  
5 the synthetic bioabsorbable material comprises oxidised regenerated cellulose.

20. A process according to any of claims 12 to 19, wherein  
the layer of synthetic bioabsorbable is a knitted, woven or  
10 non-woven mesh or web.

21. A process according to any of claims 12 to 20, further  
comprising the step of dispersing an antibiotic, an  
antiseptic or an anti-inflammatory compound in the said oil-  
15 in-water emulsion.

22. A process according to any of claims 12 to 21, further  
comprising the step of dispersing a growth factor, a  
cytokine and/or a glycosamino glycan in the said oil-in-  
20 water emulsion.

Patents Act 1977  
 Examiner's report to the Comptroller under Section 17  
 (The Search report)

Application number  
 GB 9319273.0

**Relevant Technical Fields**

(i) UK Cl (Ed.L) A5R (RAG, RAM, RAP, REL); D1R (RFA, RFZ)

(ii) Int Cl (Ed.5) A61L 17/00, 27/00

Search Examiner  
 MISS M M KELMAN

Date of completion of Search  
 23 NOVEMBER 1993

**Databases (see below)**

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASES: WPI, MEDENG

Documents considered relevant following a search in respect of Claims :-  
 1 TO 22

**Categories of documents**

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